VI. "The Calculus of Chemical Operations.—Part II. On the Analysis of Chemical Events." By Sir B. C. Brodie, Bart., F.R.S., late Professor of Chemistry in the University of Oxford. Received January 13, 1876.

(Abstract.)

Introduction.—An account is here given of the origin of our views of the constitution of ponderable matter, regarded as constituted of units compounded of "simple weights." These considerations lead to two systems, and two only, in which the unit of hydrogen is respectively expressed by the symbols α and α^2. Between these systems we have no absolute means of selection; but a preference is here given to the system α as immediately leading to the law of even numbers.

The exception presented by the binoxide of nitrogen is then considered, and an hypothesis suggested to account for this anomaly.

The object of the work is then defined—namely, given a chemical event, how are we to determine the events of which it is compounded?

Section I.—The *question of the Multiplication and Division of chemical equations* is here considered. It is shown that we may multiply and divide a chemical equation of the form $u=0$ by any chemical function, if the sum of the numerical coefficients in that equation is equal to zero, but otherwise not. A method is given by which every chemical equation may be brought under this form. Such an equation is termed a "normal" chemical equation, for it is an equation on which we may operate by the rules of elementary algebra.

It is then shown that every chemical expression of the form $A(x-a)(y-b)$, and also $A(x-a)(y-b)(z-c)\ldots$ (that is, the continued product of any number of such factors more than one), necessarily $=0$.

As regards the interpretation of normal chemical equations. Normal equations express the identity of the two members of the equation, not only as regards matter, but as regards matter and space also. Thus the equation $1+2\alpha\xi=2\alpha+\xi^2$ asserts not only that the matter of two units of water is identical with the matter of two units of hydrogen and a unit of oxygen, but also that an empty unit of space and the space occupied by two units of water are identical with the space occupied by two units of hydrogen and a unit of oxygen.

It is further shown that in any chemical equation any one of the prime factors of the equation may be substituted for another, and the equation will still be true.

Section II.—Our knowledge of the identity of matter is derived from chemical transmutations or events; and every chemical equation may be regarded as the record of such an event or some number of such events. Chemical events may be regarded as compound or simple. A compound event is defined as an event which is regarded in the system of events under our consideration as constituted of two or more events. A simple

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event is an event which is not so regarded. Thus, for example, take the system of the four events :—

$$\begin{array}{lllll} (1) & \alpha^2\nu + \alpha^3\kappa^2\omega & = \alpha\omega & + \alpha^4\kappa^2\nu, \\ (2) & \alpha^4\kappa^2\nu + \alpha^3\kappa^2\omega & = \alpha\omega & + \alpha^6\kappa^4\nu, \\ (3) & \alpha^6\kappa^4\nu + \alpha^3\kappa^2\omega & = \alpha\omega & + \alpha^8\kappa^4\nu, \\ (4) & \alpha^2\nu + 3\,\alpha^3\kappa^2\omega & = 3\,\alpha\omega & + \alpha^8\kappa^6\nu. \end{array}$$

The event 4 is a compound event, being the aggregate of the events 1, 2, 3; whereas the events 1, 2, 3 are in that system simple events, being incapable of such a construction.

Section III. *On the causes of events.*—The cause of an event is given when the operations are defined by the agency of which the event occurs. *Def.* If in any chemical event the change in the arrangement of the symbols, by which the composition of the units of matter before and after the event respectively is symbolized, be of such a nature that where in the arrangement before the event the symbol x appears the symbol a appears after the event, and where a appears before x appears after, so that the two arrangements differ in this respect and this respect alone, then the event occurs by the substitution of a for x, which is the "cause" of the event. Hence the same event may arise from more than one cause. Thus, for example, the event

$$\mathrm{A}xy + \mathrm{A}ab = \mathrm{A}ya + \mathrm{A}xb$$

occurs by the substitution of a for x and of b for y, for these symbols satisfy the condition given in the above definition.

It is similarly shown that the event

$$\mathrm{A}xyz + \mathrm{A}abz + \mathrm{A}ayc + \mathrm{A}xbc = \mathrm{A}xyc + \mathrm{A}abc + \mathrm{A}ayz + \mathrm{A}xbz$$

occurs by the substitution of a for x, b for y, z for c; and, further, that if the equation to any chemical event be of the form $\mathrm{A}\,(x-a)\,(y-b)\,(z-c)\,(v-d)\,(w-e)\ldots = 0$, that event occurs by the substitutions of a for x, b for y, c for z, d for v, e for w . . . .

If in these substitutions any symbol, say 'a'$=1$, the event occurs by the transference of the simple weight thus symbolized.

The following event occurs in three ways by the substitution of ξ for χ, the hydride of propyl, $\alpha^4\kappa^3$, being constant,

$$\alpha^4\kappa^3\chi^3 + 3\alpha^4\kappa^3\xi^2\chi = \alpha^4\kappa^3\xi^3 + 3\alpha^4\kappa^3\xi^2\chi,$$

the equation being of the form

$$\alpha^4\kappa^3(\chi - \xi)^3 = 0.$$

Similarly the event

$$\alpha^2\kappa\chi^3 + 3\alpha^2\kappa\chi = 3\alpha^2\kappa\chi^2 + \alpha^2\kappa$$

is an event occurring in three ways by the transference of χ, the equation being of the form

$$\alpha^2\kappa(\chi - 1)^3 = 0.$$

I submit the following equation to the consideration of the reader,

$$\alpha^4\kappa^3\xi\,(\beta - \xi)\,(\chi - \xi)\,(\alpha\kappa^2\xi - 1) = 0.$$

Section IV. *Elementary analysis of events.*—If the equation to a chemical event be capable of expression as the continued product of rational factors of the form previously given $(x-a)$, x and a being prime factors of the equation, the event is a simple event incapable of further resolution; but occasionally the equations to events may be expressed by rational factors, although not of this form. In this case they admit of an easy analysis into other events of which they are the aggregates. Take, for example, the equation

$$a\chi^2+2a\omega=2a\chi+a\omega^2,$$

or

$$a(\chi+\omega-2)(\chi-\omega)=0,$$

which may be written thus,

$$a(\chi-1)(\chi-\omega)+a(\omega-1)(\chi-\omega)=0,$$

whence

$$a(\chi-1)(\chi-\omega)=0,$$
$$a(\omega-1)(\chi-\omega)=0,$$

the constituents being

$$a\chi^2+a\omega=a\chi+a\omega\chi,$$
$$a\omega\chi+a\omega=a\omega^2+a\chi.$$

Again, the following event is the action of chlorosulphuric acid upon water:—

$$a\theta\xi^2\chi^2+2a\xi=a\theta\xi^4+2a\chi.$$

This equation is of the form

$$a(\theta\xi^2+\theta\xi^3-2)(\chi-\xi),$$

whence

$$a(\theta\xi^2\chi-1)(\chi-\xi)+a(\theta\xi^3-1)(\chi-\xi),$$

the constituents being

$$a\theta\xi^2\chi^2+a\xi=a\theta\xi^3\chi+a\chi,$$
$$a\theta\xi^3\chi+a\xi=a\theta\xi^4+a\chi.$$

The analysis of these two phenomena here indicated has actually been effected by experiment.

Section V.—In this section the doctrine of *Chemical Congruity* is discussed, two chemical functions being said to be congruous to one another in reference to a special substitution if they assume the same value when that substitution is respectively effected in them.

Further, a method is given for the *Development of chemical functions*, and for the complete theoretical analysis of any chemical event whatsoever—the theoretical analysis of a chemical event occurring by any number of specified substitutions, namely, of a for x, b for y, c for z, . . ., being here said to be effected when all the different chemical events occurring in any way whatever by these substitutions are enumerated, the aggregate of which constitutes the event in question.

I shall not attempt any further abstract of this section, which is given in my memoir with as much brevity as is consistent with the comprehension of the subject.